Pan-Africa Bean Research Alliance
Better Beans for Africa

Bean technology adoption and its impact on smallholder farmers' productivity, bean consumption; and food security: *Evidence from Zimbabwe*

SDC PROJECT ENDLINE REPORT 2020

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List of Acronyms

ABC	Alliance for Bioversity International and International Center for Tropical Agriculture
ATET	Average Treatment of the Treated
CAPI	Computer Assisted Personal Interviewing
DNA	Deoxyribonucleic Acid
DID	Difference in Difference model
DR&SS	Department of Research and Specialist Services
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FCS-N	Food Consumption Score Nutritional Quality Analysis Guidelines
FSCgp	Food Consumption Score Group
GAC	Global Affairs Canada
HFIA	Household Food Insecurity Access Scale
HFIAS	Household Food Insecurity Access Scale
HDDS	Household Dietary Diversity Score
HH	Household(s)
HHS	Household Hunger Scale
ICM	Integrated Crop Management
IPWAR	Inverse Probability Adjustment Regression
MDDS	Minimum Dietary Diversity Score
MDD-W	Minimum Dietary Diversity for Women of Reproductive Age
METEM	Multinomial Endogenous Treatment Effects Model
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares
PABRA	Pan Africa Bean Research Alliance
PVS	Participatory Varietal Selection
PSM	Propensity Score Matching
PICS	Purdue Improved Crop Storage
SDC	Swiss Agency for Development and Cooperation
TLU	Total Livestock Units

Executive Summary

In 2015, the Pan Africa Bean Research Alliance (PABRA) programme of the Alliance of Bioversity International and the International Center for Tropical Agriculture (Alliance) started implementing a project on **"Improving bean productivity nutrition, incomes, natural resource base and gender equity for better livelihoods of smallholder households in Sub-Saharan Africa,"** with financial support from the Swiss Agency for Development and Cooperation (SDC) and Global Affairs Canada (GAC). This study was conducted to assess the outcomes of the six -year project intervention in Zimbabwe. Burundi and Zimbabwe were selected as the flagship countries for this project. . The study used two rounds of data collected in 2016 and 2018 from the same households that were selected from the bean producing areas of Zimbabwe using a two-stage stratified sampling method. The data was analyzed using a difference in difference method and Multinomial Endogenous Treatment Effects Model (METE).

The results confirm that flagship interventions in Zimbabwe have had significant and positive impacts on the livelihoods of bean producers. Interventions in seed systems have increased the availability of quality seed in the community and positively influenced seed demand. The average distance between a village to the nearest seed dealer fell by 60%, from an average of 25 kilometers in 2016 to about 10 kilometers in 2018. Demand for certified seed increased by close to 3.0 kilograms per producer. The adoption of improved varieties promoted by the project has improved almost fivefold, from its baseline rate of 9% in 2016 to about 47% of the surveyed households in 2018. We uncover one finding- on the complementarity of varieties and good management on enhancing bean yield. Previous impact work had focused on varieties alone without accounting for the contribution of agronomy when evaluating the impacts of adopting improved varieties. Higher productivity gains were realized when improved varieties were also better managed, using a combination of climate-smart organic soil fertilizers notably vermi-composite, Rhizobium inoculant, organic/green manure, conservation agriculture and climate-smart information. Through increased yield and expansion of production area, bean farmers have raised the per capita bean consumption by about 0.65 kilograms per agricultural season. Our findings show that the project has had a positive contribution on food security of poorer households—reducing the percentage of households with the unacceptable Food Consumption Score (FCS) (i.e. with FCS <28) by 9 percentage points, from a baseline of 12% in 2016 to 3%in 2018. Overall, the food consumption score among the interviewed households increased by 4 points, equivalent to one day of animal-based meal. One notable finding is associated with higher food consumption gains for households farming under rainfall conditions that exposes them to climatic variations. This highlights the effectiveness of resilient varieties and good management on curbing yield loss to ensure food security. The study findings provide some valuable lessons:

- The impact of improved beans is higher when adopted together with better crop management practices
- Better access to seed helps farmers' increase demand of quality seed, expansion of bean area and use of recommended good agricultural practices—thereby achieving positive yield gains
- While there has been improvement in household bean consumption, most of it is still dependent on a farmer's own ability to produce, with vulnerability to climatic variations. Thus, addressing malnutrition through biofortified beans requires a concerted effort to simultaneously address the problem of seed access and challenges posed by climatic variation.
- A typical farmer in Zimbabwe grows an improved bean variety for a shorter period of time. This pattern likely reflects greater stresses emanating from climatic variability, making communities vulnerable and highlights seed insecurity that warrant frequent introduction of new varieties.

1.0 Introduction

TThe Pan-Africa Bean Research Alliance (PABRA) and SDC supported project was designed to contribute to the food security, nutrition, incomes and gender equity of smallholder farmers through improved bean productivity and consumption. The objectives of the project were therefore to develop pro-poor technologies and create collaborations with a diverse set of both private and public sector partners among them HarvestPlus, extension personnel, NGOs, private seed companies and input suppliers, agro-dealers and farmer organizations, etc., to facilitate uptake of technologies at scale. The project started in 2015 in all PABRA member countries of East and Southern Africa with emphasis on Burundi and Zimbabwe as project flagship countries. The project received financial support from (SDC) through the PABRA program of the Alliance of Bioversity International and the International Center for Tropical Agriculture (ABC). It offered a range of interventions, from improved varieties, integrated crop management practices, seed systems, markets, nutrition and gender, along the bean value chains. The project also leverages funds from the Global Affairs Canada (GAC) and Technologies for African Agricultural Transformation (TAAT). The project also developed an evaluation system in flagship countries based on quasi-experimental methods, with a population-based household survey at baseline and end line across bean growing communities. The purpose was to measure short and medium term outcomes of the activities implemented along the bean value chains under the flagship countries. The impact component applied the theory of change to identify and select outcomes to include in the study.

This report provides results of the ex-post impact assessment study conducted in 2018 and 2019 in Zimbabwe, comparing them with results to the baseline undertaken in 2016. The study aims to address the extent to which project interventions have influenced bean production, utilization of associated technologies promoted and household welfare. The study analyzes the success of the project using difference in difference method, but also draws lessons about what worked, what did not work well and why. The difference in difference approach is complemented by econometric methods to identify effects on the adoption on yield and consumption while controlling for other covariate factors. In the next section, this report presents background information on the study context, flagship project intervention and objectives. An overview of the methodology employed for the impact assessment study is presented in section four, with results and conclusions to follow.

2.0 Background Information on the Flagship Interventions

At the start of the project in 2015, the bean subsector in Zimbabwe was experiencing a number of challenges that resulted in dramatic productivity decline (67%) between 2010 and 2015. The common bean was also transitioning from a large scale commercial farm crop to a small scale farmers' crop, following land reform in the country. For many farmers, yield gap was conspicuously wide; the national average yield was less than 500 kilograms per hectare (AGRITEX 2015), just five-fold less than the crop potential yield of above 2700 kilograms per hectare (Mutari and Hodzi 2015). The bean yield gap was attributed to climate change-driven variable weather patterns that resulted in increased incidences and severity of biotic and abiotic stressors (Mutari and Hodzi 2015). Small scale producers in communal lands who produce over half of the national bean grain output, operate in drought-prone areas without irrigation, and lacked appropriate expertise[1] in bean production and technologies to deal with the challenges. For example, during baseline studies, farmers (61%) were not aware of the names of the varieties they had planted;

1 Land reform policy resulted in the transformation of the agricultural set up from a well-established, large-scale commercial enterprises to small-scale and newly resettled farmers.

(47%) of farmers obtained yield less than 500 kilograms per hectare (Katungi et al., 2017). Bean productivity was also hit by climatic variability, leading to seed-borne diseases and breakdown of genetic resistance due to the emergence of new virulent pathogens.
The aforementioned challenges were made worse by macroeconomic policies that were biased towards cereal and cash crop production between the year 2000 and 2014. Among these was a government drive to produce tobacco and maize, which marginalised investment in the bean subsector. As a result, national bean research and extension staff had limited capacity to respond to farmers' needs, and were unable to support the bean processing industry after the transformation of the agricultural sector in the post land policy reform era. As a consequence, the bean processing canning industry had to rely on bean imports to keep functioning. But this increased the price of canned beans, making it unaffordable by the majority poor. Production reduced for other bean types as well, which led to higher prices and consequent reduction in bean consumption. For example, a good price for bean grain at informal markets ranged from US$800 to US$1,000 per ton.

Following the collapse of the beef industry and growing concerns of possible nutrition insecurity in the country at the time, the government decided to prioritize common bean for nutritional interventions given its importance as a source of protein and micronutrient. However, the people had negative perceptions about beans as an inferior food eaten in prisons, hospitals and boarding schools. Thus, changing attitudes and perceptions, especially among urban consumers and producers, was crucial in promoting production and consumption of beans in the country. Moreover, private sector seed companies and canners were operating well below capacity. If revitalized, they could in-turn re-invigorate Zimbabwe's bean sub-sector.

2.1 Flagship Interventions and their Implementation

The PABRA and SDC project interventions targeted farming households that theoretically have land to benefit economically from expanding and diversifying production, yet remain vulnerable to external shocks, such as climatic or economic turbulence. Specifically, these are households that have the potential to improve bean productivity and expand their area for beans if provided with appropriate technology, information and have access to profitable markets. The project focused on: i) developing and disseminating high-yielding bean varieties that are resilient to biotic and abiotic production constraints and good agronomic practices; ii) linking farmers to input markets, financiers and profitable grain markets; iii) building capacity of researchers within the implementing national institutions,

TABLE 1 Type and name of partners engaged in ICM and seed systems, Zimbabwe under the flagship project

COMPONENT	PARTNER TYPE	PARTNER NAME	ACTIVITIES
ICM	NGOs/ international initiatives	Cluster Agricultural Development Services [CADs],	Sensitising and training farmers on Bean management practices and inputs
		Lead Trust, Feed The Future, Practical Action (Markets Component)	
Capacity building	Agro-dealers	(Farm and City, Shalom agro chemicals, Syngenta, ZFC Limited),	
	GOVT EXT	AGRITEX	
Seed systems	Seed companies	Seed Ridge and Mkushi Seeds, National Tested Seeds, ARDA Seeds	Multiplication of NUA4
Grain processors	Bean processors	Cairns Food Limited, Olivines Limited, and Africa Preserves	Processors - grain and canning industry

value chain actors and farmers and; iv) influencing the consumption of bean through nutrition education in project communities. These interventions were identified based on the experiences of PABRA in Zimbabwe with particular reference to the production constraints alluded to in section 2.0 of this report.

The project's target was to reach 750,000 smallholder farming households with high-quality seed of improved varieties, and Integrated Crop Management (ICM) options. According to the Monitoring, Learning and Evaluation (MLE) records, the flagship project worked to assist a minimum of 500,000 households by 2018, increasing from 300,000 households in 2015 and reaching 945,000 farmers within a period of three years between 2015 and 2018. Some farmers accessing ICM technologies were trained in bean production or basic nutrition skills and practices. A total of 46,672 men and women have participated in various capacity building initiatives since 2015.

The project was able to reach its target by forming partnerships with established companies (See Table 1), aligning objectives with government policies. Government programmes on compulsory food fortification to enhance nutrition that begun in 2015[2], stimulating demand for biofortified beans. This in turn triggered some seed companies (Zadzamatura, Mukushi Seeds and African Granaries), which were earlier hesitant to market government developed bean varieties, to start multiplying and marketing biofortified bean varieties. Those companies that had scaled down the multiplication of bean varieties also increased production in 2017 in response to increased demand. The project also leveraged existing viable ICM technologies and mass media to support information dissemination for example through billboards and online; and a well-established input supply chain for most chemicals to reach many farmers with ICM technologies[3].

Government institutions with expertise in agricultural extension, nutrition and gender worked at national level with the Department of Research and Specialist Services (DR&SS) and AGRITEX to build farmer capacity on agronomic practices, nutrition sensitization and gender mainstreaming. All stakeholders were brought together and defined their roles in the project, developing project road maps and setting annual targets. The same stakeholders convened annually to review achievements against set targets, as well as shared experiences to draw lessons. Through these processes, new activities were added, while original strategies were revised to serve the needs of target beneficiaries.

2.2 Coverage

The SDC flagship project was implemented in 17 districts selected across all bean producing provinces. The districts are: Matobo, Mwenezi, Gweru, Masvingo, Chikomba, Sanyati, Zvimba, Seke, Marondera, Makoni, Nyanga, Mutasa, Murewa, Uzumba Maramba Pfungwe, Chimanimani, Chipinge and Harare. Figure 1 shows locations of intervention activities and sites for the baseline survey.

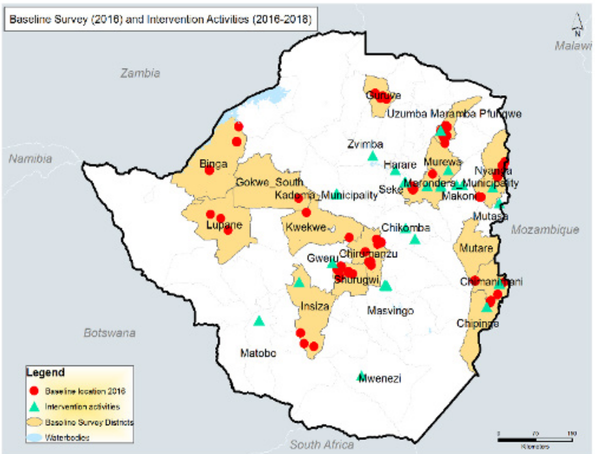


FIG 1 Map showing flagship interventions and survey sites

2 Since 2015, there has been increased emphasis on nutrition by government & NGOs following the launch and adoption of the compulsory food fortification strategy and the national school feeding program.

3 However, majority of the farmers accessed synthetic pesticides, fertilizers, chemicals disseminated through different partners (NGOs, private companies, agro-dealers) which might enhance productivity of beans with unknown impact on profitability, since conventional inputs are high cost bean inputs.

3.0 Study Objectives

This study sought to achieve the following objectives:

- Examine the farmers awareness perceptions and use of improved bean technologies promoted under the flagship project
- Assess short and medium-term effects of the project on access and demand for quality seed and food consumption frequency
- Evaluate the adoption of multiple improved bean varieties with their associated crop management practices and their impact on bean yield and bean consumption.

4.0 Study Methodology

4.1 The data

The study uses two data sets: baseline data sets and end line data sets collected by the DR&SS and AGRITEX[4] in collaboration with PABRA scientists. The baseline sample was designed in 2016 by developing a sampling frame, purposively selecting 15 districts with a larger area under bean production in 2015. Then, we listed wards in selected districts and classified them as intervention and non-intervention wards, randomly selecting wards from each stratum. This was followed by random selection of bean growing households from each selected ward for the survey. The baseline survey was conducted in the first year in 2016 while the end line survey was undertaken in 2018, the fourth year of the project, collecting data from the same households surveyed in 2016. In each period, information was also collected at community level through focus group discussions, used to assess the extent of spillover effects by profiling direct and indirect intervention communities. By collecting data from the same households and communities, we aimed to address potential unobservable effects assumed to be fixed over the three years.

4.2 Data Analysis

4.2.1 Difference in Difference (DID) Method

A difference in difference method was used to analyse the changes between different sub-samples of households in the two strata (i.e. with the intervention and without the intervention). In particular, we compare changes in the selected outcome variables of the households in the wards receiving the interventions (w) and the households in wards without the intervention between 2016 and 2018.

$$\textbf{DID} = (Y_{2018} - Y_{2016})w \; - \; (Y_{2018} - Y_{2016})1 - w$$

4.2.2 Econometric Approach

Our econometric approach applied a (METE) model to estimate the adoption of bean technologies on bean yield and bean consumption. The technology package includes: improved varieties and organic soil fertility management practices such as organic manure, vermi-compositing, and Rhizobium inoculum and conservation agriculture. These were promoted under the project for their low-cost and technical effectiveness on enhancing bean productivity, while increasing resilience to climate variability. Since the use of each of these management practices was low, we combined the four practices and defined their adoption as use of either one of them. This resulted in two types of technologies in the analysis package, i.e. organic soil fertility management practices and improved varieties. The econometric analysis is based on the data set collected in 2018 that contained complete information about crop management practices and varieties. As outcome indicators, we used bean yield per kilogram of grain produced per kilogram of seed planted; and quantities

4 Through workshops held in Zimbabwe, the team jointly defined the outcome indicators, developed sampling frame and survey tools. This approach is used because of its contribution to capacity building of national teams in designing and implementing the impact evaluation.

of bean in kilograms consumed per person in the household during the agricultural season of the study. Food security was represented by the Food Consumption Score (FCS), which is the frequency weighted dietary diversity score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey (WFP, 2008). FCS is an acceptable proxy indicator to measure caloric intake and diet quality at household level, based on dietary diversity, food frequency, and relative nutritional importance of different food groups.[5]

5 WFP/VAM, 2015: Food Consumption Score Nutritional Quality Analysis Guidelines (FCS-N).

5.0 Results and Discussion

Results of the study are discussed in two sub-sections, i.e. 5.1 & 5.2. Sub-section 5.1 presents the estimates of changes in technology access and utilization; bean yield measured by seed multiplication ratio; and food consumption score¬–an indicator of food security–derived from a difference in difference method. Data of 2016, served as baseline. Results in sub-section 5.2 are estimates from econometric analysis of the effect of bean technology adoption on bean yield and bean consumption.

5.1 Quantitative Comparisons of Outcomes by DID Method

5.1.1 Availability and access to quality seed

Effect on seed availability

To address seed constraints, the flagship interventions in the seed systems aimed to increase the availability of quality seed, making it more accessible through innovative marketing strategies. The market activity component aimed to enhance profitability of value chain actors to increase farmers' incentive to invest in quality seed. As part of the impact assessment, we investigated whether there were changes in the seed availability and demand that can be attributed to flagship interventions.

Results indicate significant improvement in the availability and access to quality seed by farming communities, which was one of the performance indicators under the seed systems. For example, the project intervention wards saw a significant reduction (60%) in the average distance between the village and seed dealer, from the average of 25 kilometers in 2016 to about 10 kilometers in 2018. The distance to seed dealers remained unchanged at 36 kilometers in non-intervention wards. This suggests that through partnerships created and managed under the flagship, seed suppliers expanded their business to cover more farming communities, either by opening new seed supply outlets or by influencing growth in agro-dealer input shop networks. This resulted in impressive improvements in seed availability within farming communities in relatively close proximity—leading to a reduction in the average distance within which farmers can access quality seed when they want it.

The project also invested in the production of early generation seed to support companies and reach more farmers. According to monitoring and evaluation data, eleven companies (i.e. Green Trade Seeds, Mkushi Seeds, Agri Seeds, IQ Farmer, African Granaries, Klein Karoo (K2), ARDA Seeds, National Tested Seeds, Zimbabwe Super Seeds, Champion Seeds, and Zadzamatura/Tocek) were supported by the project to produce foundation and certified seed.

Effect on seed demand

Seed demand at farm level has also increased, with more farmers purchasing and planting certified bean seed. Between 2016 and 2018, the average quantities of seed purchased per producer, farming under rain-fed systems in non-intervention wards increased from 8.7 to 13.1 kilograms, while it grew two-fold from 6 to 12 kilograms in intervention areas under similar production systems. The DID of 0.95 was however not significant to suggest that the change was associated with the project. In other words, the difference in seed demand between intervention and non-intervention after comparing the two years was small and could not be associated with the project intervention. For farmers growing beans under irrigation systems, there was an expansion of bean area in non-intervention wards that resulted in growth in seed requirements among this group. This additional seed requirement was met from own saved seed. Irrigated farms in the intervention areas increased their seed purchases from an average of 14 kilograms in 2016 to 33 kilograms in 2018. Compared with irrigated farms in non-intervention wards, the irrigated farms in intervention wards increased they seed demand by 8.8 kilograms that was significant at 5% level (table 2), attributable to the flagship project. We attribute this positive effect on seed demand to two factors: the increase in supply of certified seed after seed companies partnered with DR&SS for

TABLE 2 Farmers' access, demand for quality seed and quantity of seed planted in 2016 and 2018 (in parentheses are standard deviations)

	NON-INTERVENTION		INTERVENTION		DIFFERENCE 2018-2016		DID (NON-INTERVENTION WARDS - INTERVENTION WARDS)
					NON-INTERVENTION	INTERVENTION	
Non-irrigated bean	**2016**	**2018**	**2016**	**2018**			
Quantity of seed planted (Kg)	19.63	30.84	12.53	19.22	11.21***	6.69***	4.52
	(23.69)	(35.91)	(13.81)	(18.55)	(34.48)	(14.50)	
% Households purchasing seed	55	60	63	74	4.58	0.11.3^	-0.062
	(47)	(49)	(46)	(44)	(0.64)	(53)	
Quantity of seed purchased (Kg)	8.67	13.09	6.25	11.62	4.42***	5.37***	-0.95
	(15.76)	(20.17)	(10.55)	(17.27)	(23.35)	(14.68)	
Price of seed	1.99	2.07	1.89	1.85	0.08	-0.04	0.122
	(1.12)	(1.23)	(0.75)	(0.81)	(1.32)	(0.57)	
Irrigated bean							
Quantity of seed planted (Kg)	23.84	46.89	31.37	45.52	23.05***	14.15***	8.90
	(59.30)	(97.06)	(83.92)	(86.75)	(70.87)	(59.70)	
% HH purchasing seed	0.57	0.62	0.72	0.79	0.06	7. 84**	-0.02
	(0.48)	(0.49)	(0.41)	(0.41)	(0.57)	(48)	
Quantity of seed purchased (Kg)	11.92	22.56	13.89	33.36	10.63***	19.48***	-8.84**
	(56.73)	(73.48)	(47.70)	(69.65)	(31.71)	(63.86)	
Price of seed	2.12	2.14	2.35	2.30	0.03	-0.05	0.07
	(0.91)	(1.03)	(0.97)	(1.01)	(1.06)	(0.94)	

the project implementation (table 1); and investment into production of early generation seed, which is often a constraint in seed systems.

Thus, the project increased farmers' access to quality certified seed but the gains went to farmers in irrigated production systems. The favourable price of certified seed in intervention areas coupled with the ability to manage climatic variation through irrigation enables farmers to increase their quantity of certified seed. The average price of certified seed faced by farmers in non-intervention areas was high, at US$3.3 in 2016, but later dropped to US$2.3 per kilogram in 2018 (Table 2). On the other hand, the price of certified seed remained relatively stable between US$2.27 and US$2.37 in intervention areas. Government policy did devalue the Dollar between 2015 and 2018, with seed prices pegged at US$5 per kilogram, but the intervention areas were less affected since the private seed companies were supported with production of foundation seed through project partnerships. The DID) of US$0.73 was statistically significant at 10%. This means that the farmers in intervention wards experienced lower growth in prices as compared to farmers in non-intervention wards, thanks to the project that was able to save farmers in intervention wards a price change of $0.73; thereby the project was able to cushion farmers from high prices.

Do you access enough seed as desired?

When the project started, seed was unavailable, with quality and quantity seed access constrained. During the two rounds of survey, each respondent was asked how much seed they desired to plant and how much seed they actually planted. Results showed that in 2016, approximately 48% of farmers in non-

TABLE 3 Average change in the price (US$/kg) of certified seed across bean production zones by intervention

	2016		2018		DIFFERENCE (2016-2018)	
	MEAN	SD	MEAN	SD	MEAN	SD
All sample combined	2.88	2.02	2.31	1.09	0.44	2.28
Non-intervention	3.34	2.42	2.33	1.19	0.75	2.35
Intervention	2.27	1.45	2.37	0.87	0.03	2.14
Difference in difference (DID) (non-intervention ward-intervention wards)					0.73	

intervention areas planted less seed than they desired. Only 52% of farmers were able to plant the quantity bean area as desired. Following concerted efforts to distribute seed in intervention areas, the seed constraints reduced among 11% of farmers. This is to say that the proportion of producers who planted less quantity of seed than they desired reduced from 42% in 2016 to 32% among farming communities in the intervention areas (table 4).

5.1.2 Utilization of improved and biofortified bean varieties

Farm level utilization of bean technology and bean products was another indicator of project outcome. Since the data was collected from farming communities, the analysis focused on utilization of bean production technology for this indicator. Of 786 bean plots surveyed in 2018, 47% (369) were planted with the four varieties promoted under the flagship project; representing a fivefold increase in the adoption rate compared to the baseline of 9% adoption in 2016 (figure 2).

Popular adopted varieties include Cherry, Gloria and NUA 45. The adoption rate of the biofortified, NU45 variety increased from less than 2% in 2016 to 12% in 2018. The adoption rate of NU45 in 2018 was significantly higher in flagship intervention wards; approximately 21% of surveyed plots compared with 7.8% in non-intervention areas.

When earlier improved varieties, which were released before the current phase of the project are also included, the overall adoption rate for varieties released under PABRA support is about 68%. This means that farmers that have not planted flagship project varieties are still growing improved varieties; the majority of them developed and disseminated by private seed companies. Thus, improved varieties dominate local varieties, but a typical farmer in Zimbabwe grows an improved bean variety for a shorter period of time. This pattern likely reflects greater stresses emanating from climatic variability, making communities vulnerable and highlighting insecurities that warrant frequent introduction of new varieties. Among all farmers surveyed, farmers used the same variety for an average of 6.7 years in general, and five years for improved varieties. However, about 70% of improved bean growers had cultivated the variety for 1 to 3 years.

TABLE 4 Percentage of growers unable to access the full quantity of seed they desire

	NON-INTERVENTION			INTERVENTION		
	2016	2018	% CHANGE	2016	2018	% CHANGE (2018-2016)
Planted lower than desired	47.86	47.01	0.61	41.96	31.73	-11.11
Same as desired quantity	52.14	52.99		58.04	68.27	
Total	**1.000**	**1.000**		**1.000**	**1.000**	

FIG 2A Map showing diffusion of four varieties promoted in Zimbabwe under the flagship in 2016

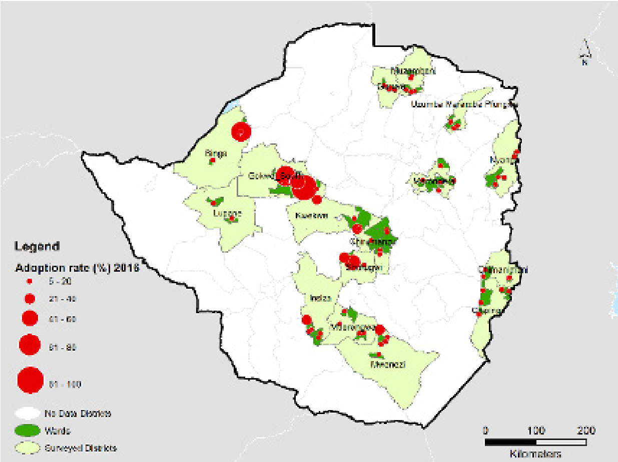
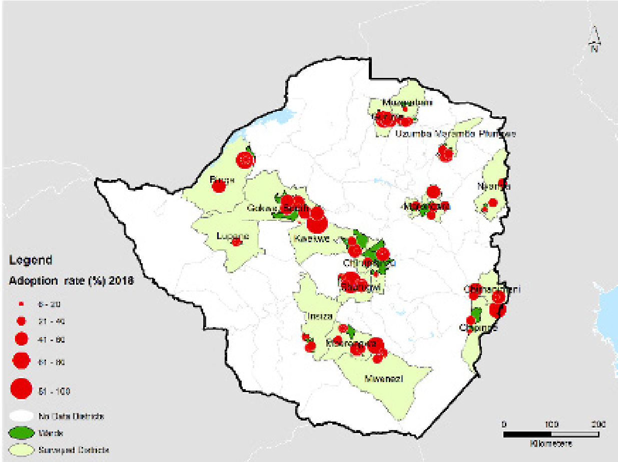


FIG 2B Map showing diffusion of four varieties promoted in Zimbabwe under the flagship, in 2018



5.1.3 Access and utilization of complementary agronomic inputs and management practices

Farmers are also using improved agronomic inputs such as inorganic fertilizers to address the problem of poor soil fertility and biotic stresses—which have been increasing (Katungi et al., 2017). For example, the share of bean growing households using basal fertilizers increased from the baseline of 72% in 2016 to 88% in 2018, an increase of 16%. The average quantities of basal fertilizer and ammonium nitrate (AN) fertilizers used also increased significantly between 2016 and 2018 for farmers, with no significant difference between intervention and non-intervention areas (Table 5).

That the project had no effect on utilization of inorganic fertilizers is not surprising, since the emphasis was on promoting low-cost organic soil fertility management practices that are climate-smart and environmental friendly. These included: vermi-composite, Rhizobium inoculant, organic or green manure, conservation agriculture and climate-smart information. Other

TABLE 5 Utilization of fertilizer and pesticides in bean production at baseline (2016) and end line (2018)[NB]

INPUTS	NON-INTERVENTION			INTERVENTION			DIFFERENCE BETWEEN 2018 & 2016			
	2016	2018	P VALUE	2016	2018	P VALUE	NON-INTER-VENTION	INTER-VENTION	DID	P VALUE
Fertilizers										
Basal kg/ha	74.6	103.6	0.001	90.3	117.3	0.006	29	26.9	2	0.861
	(88)	(98.2)		(89.8)	(95.6)					
Top dressing kg/ha	19	44	0.001	36.3	55	0.005	0.2	0.1	0.1	0.287
	(36.9)	(66.4)		(54.5)	(70.1)		(0.6)	(0.6)		
Use rates of inputs (%)										
Basal	71.7	87.5	0.003	78.8	91.7	0	15.9	13	2.9	0.472
Top dressing	37.7	58.1	0.001	56	64.2	0.074	20.4	8.3	12.1	0.028
Pesticides										
Fungicide	8.7	31.6	0.004	12.9	24.4	0.003	22.9	11.5	11.4	0.016
Insecticides	14.6	68	0.001	6.8	58.4	0	53.4	51.6	1.8	0.691
Herbicide	12.5	6.9	0.008	4.6	3.7	0.565	-5.6	-0.9	-4.7	0.075

[NB] in parentheses are standard deviations

FIGURE 3 Percentage of farmers who know and use climate-smart technologies

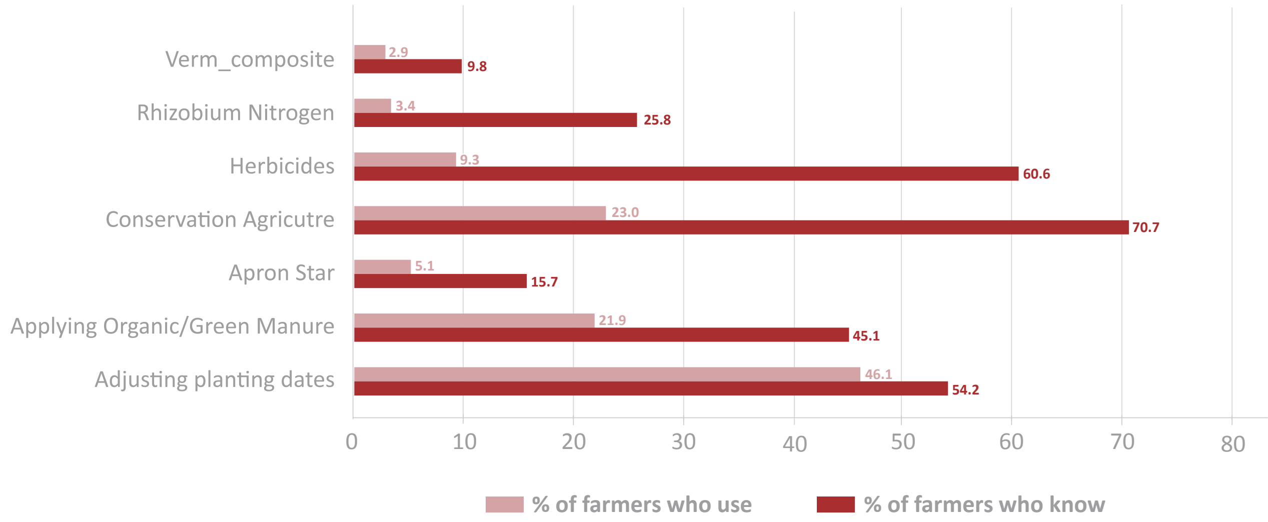
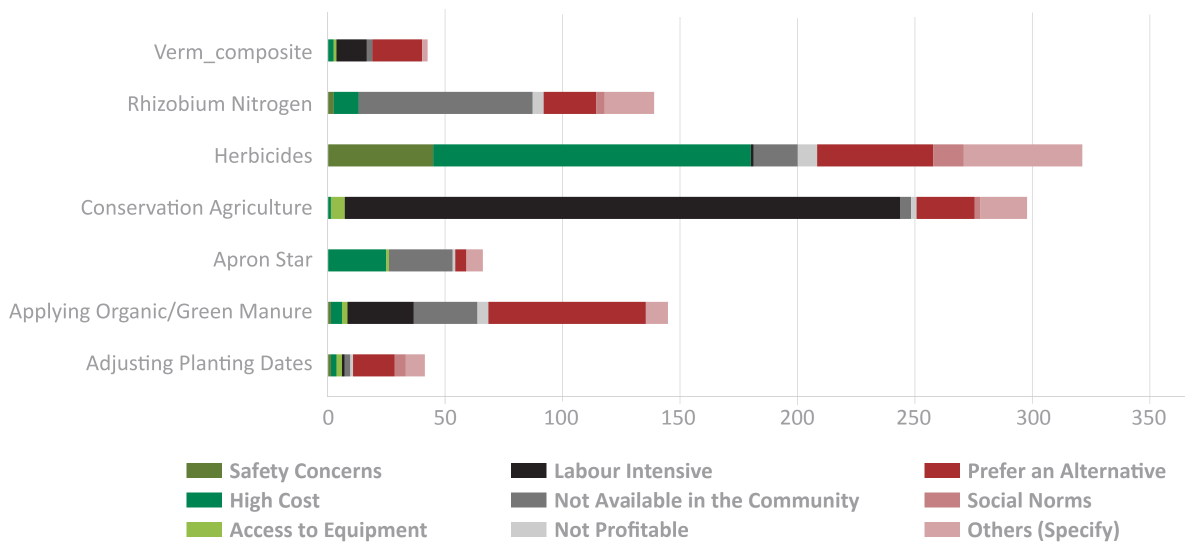


FIGURE 4 Farmers' reasons for non-use of management practice they know



inputs promoted under the flagship project aimed at reducing drudgery (i.e. pre and post emergence herbicides) and seed borne diseases (i.e. seed dressing chemical ApronStar®[6]). Since information on these crop management practices existed only in 2018, data set comparisons of endline and baseline data was not possible. Our analysis of project performance is based on farmers' reported awareness, levels of satisfaction with the technology and its utilization.

Results show that the majority of farmers were aware of climate-smart techniques such as adjusting planting dates in response to weather information, conservation agriculture, organic or green manure and herbicides (Figure 3).

However, few farmers had started using these technologies at the time of end line survey in 2018. With the exception of adjusting the cropping calendar based on weather information, the use of other climate-smart management practices or inputs in 2018 was 25% or less

6 Apron Star is a registered trademark of Syngenta. It contains Thiamethoxam (200g/kg), Mefenoxam (200g/kg) and Difeniconazole (20g/kg).

(Figure 3). Overall, low uptake of herbicide use stems from its high cost, while high labor demand is responsible for low use of organic manure and conservation agriculture (Figure 4). These adoption barriers are investigated further in a multivariate econometric analysis presented in section 5.2.

5.1.4 Changes in bean yield

We compared the yield distribution in 2016 between rain-fed farms located in non-intervention wards and those farms in intervention areas. Results in Figure 5a. showed that farmers in non-intervention areas experienced lower yield in 2016 than those in intervention areas. Both the visual inspection of figure 5 (panel a. & c.) and two Kolmogorov-Smirnov tests reveal that yield distribution on rain fed farms was significantly different between intervention and non-intervention wards in the two years studied.—Farms in intervention areas showing more favourable yields than their counterparts located in non-intervention area. For example, in 2016, approximately 60% of farmers in non-intervention areas obtained a seed multiplication ratio below 10 kilograms of grain per one kilogram of seed planted. On the contrary, same proportion of farms in non-intervention areas harvested less than 8 kg from each kg of seed they planted. A similar trend was observed among irrigated farms, meaning that farms in intervention areas were generally more productive at the beginning of the project.

In 2018, we again compared yield distribution among rain fed farms in intervention and non-intervention areas, Figure 5 (panel b. & d.), and found that the yield difference between

FIGURE 5A Yield distribution in rain fed farms in 2016 disaggregated by project intervention areas

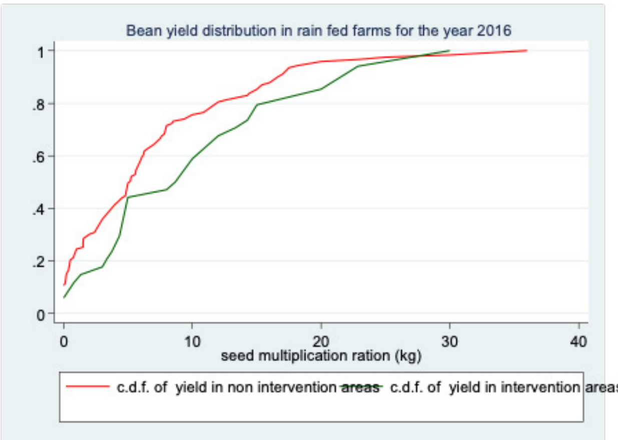


FIGURE 5B Yield distribution in irrigated farms in 2016 disaggregated by project intervention areas

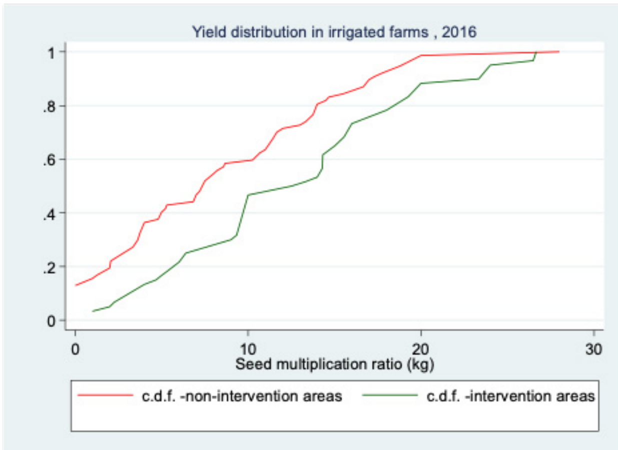


FIGURE 5C Yield distribution in rain fed farms in 2018 disaggregated by project intervention areas

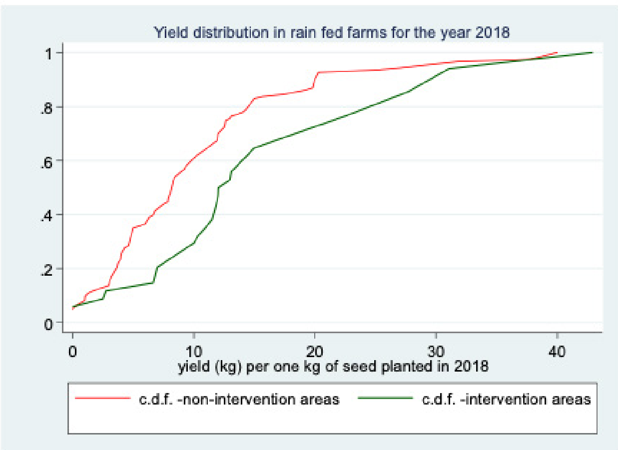
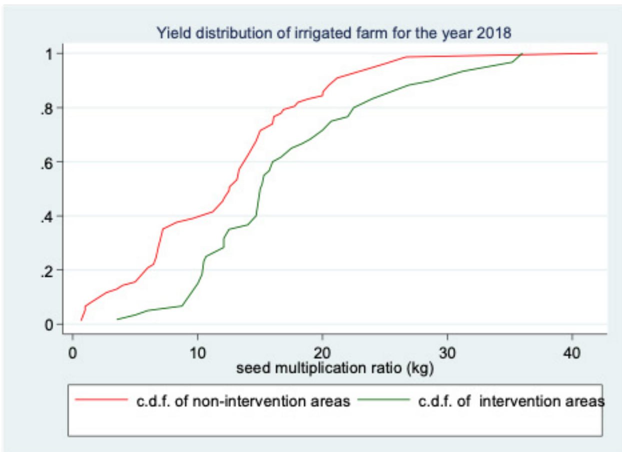


FIGURE 5D Yield distribution in irrigated farms in 2018 disaggregated by project intervention areas



these two strata had widened. For example, the percentage of rain-fed farms registering a seed multiplication ratio below 10 kilograms drastically reduced from 60% to about 30% for intervention areas while it reduced from about 75% to about 60% in non-intervention areas. This implies that the shift in yield distribution for 2018 might have affected rain fed farms differently--, with those in intervention areas performing better than their counterparts in the non-intervention areas. For irrigated farms, the yield gap between intervention areas and non-intervention areas narrowed in 2018, but the productivity remained higher among farms in the intervention areas than in the non-intervention areas (figure 5b & d). The percentage of irrigated farms harvesting less than 10 kg of grain from one kg of seed planted reduced from 60% in 2016 to about 40% in 2018 across the non-intervention areas. The change in the proportion of irrigated farms with harvests below the 10 kg per one kg of seed planted in the intervention areas was relatively smaller —dropped by about 10% between 2016 and 2018.

In table 6, we examine yield changes among irrigated and rain-fed farms separately. In both systems, the results suggest that the farms in intervention areas were relatively more productive in 2016 and 2018 compared with those in non-intervention areas. However, the effect was significant only for farms in rain-fed agriculture—showing a difference in difference of (DID) of 2.5 kilograms of grain per 1 kilogram of seed planted between farms in intervention and non-intervention wards. This is equivalent to a yield gain of 25% above the baseline average of 105 kilograms per kilogram of seed planted among rain fed farms attributed to the project for rain fed farms (table 6). The growth of 0.4 kilograms per kilogram of seed among irrigated farms was small and not statistically significant, perhaps because by irrigation, these farms were already empowered with production resources. Thus, the yield impact is higher among rain-fed farms, which we attribute to adoption of resilient varieties and better agronomic practices promoted by the project in these areas. Aggregately, the project made an average effect on yield of 11.5%.

5.1.5 Change in household food security

Food security of many smallholder bean producers is dependent on rainfall patterns. Three years ago, in 2016, the average FCS of bean growing households was estimated at 60.8. The diets were mainly composed of starch and vegetables and to some extent high consumption of oil and sugar. In 2018, the average household diet remained the same, but the FCS shifted upwards, lowering the overall score from the average of 60.8 to 57.6 (table 7). Generally, households in intervention areas had a lower food consumption frequency than the households in non-intervention areas (Table 7). Noteworthy is that the FCS reduced for households already above a FCS of 50 in 2016 while it increased for households who were in unacceptable FCS during the time—thus considered food insecure (Figure 6 a. &b.).

TABLE 6 Difference in Difference (DID) estimation of changes in bean yields (kg/one kg of seed planted

		NON-INTERVENTION		INTERVENTION		Difference 2018-2016		DID (1-0)	P-value
		2016	2018	2016	2018	Non-Intervention	Intervention		
Non-irrigated bean		7.08	10.24	10.46	16.08	3.16	5.62	2.46076	0.012
	SD	7.29	8.69	8.44	10.97	5.05	6.01		
Irrigated farms		8.43	12.40	12.80	17.24	4.03	4.44	0.40999	0.553
	SD	6.50	7.52	6.88	7.84	6.14	5.42		
All sample		7.60	11.07	11.96	16.82	3.49	4.87	1.37279	0.048
	SD	7.01	8.31	7.52	9.06	5.50	5.64		

FIG 6A Comparing Food Consumption Score for 2016 and 2018 in non-intervention areas

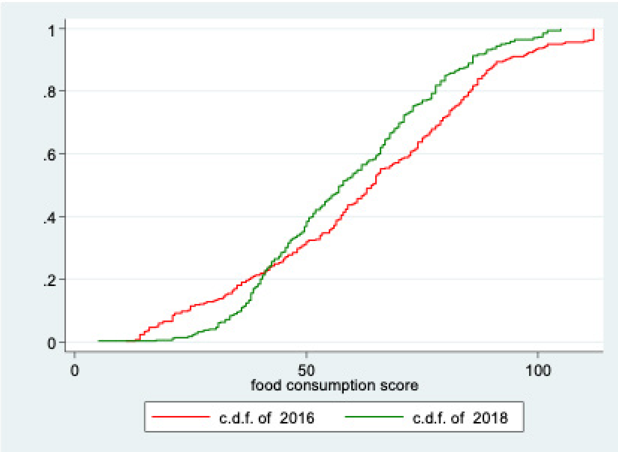
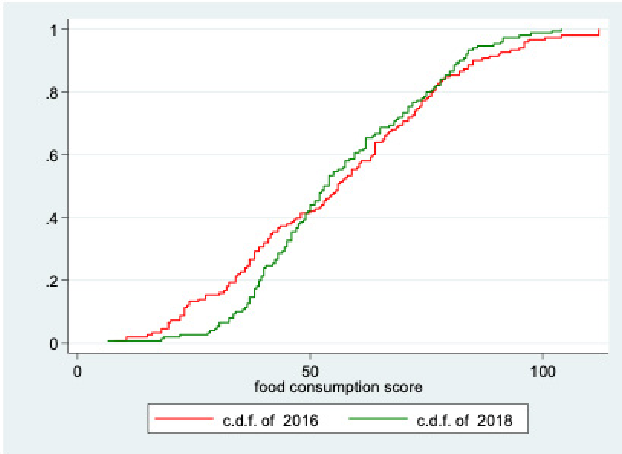


FIG 6B Comparing Food Consumption Score for 2016 and 2018 in intervention areas



Heterogeneous variations in food consumption that favoured poorer households in the year 2018 occurred in both the intervention and non-intervention wards, but the point of inflection was slightly different. The FCS increased for 20% of households at the bottom of food consumption distribution in non-intervention wards, while it increased for about 40% of the households in intervention areas. The percentage of households in the unacceptable consumption group (i.e. with FCS <28) reduced by 8.7% from a baseline of 12% in 2016 (Table 7).

Table 7 also indicates a significant increase in the consumption frequency of vegetables from the 3.0 to 4.3 days per week by poorer households. This is linked to nutritional trainings that targeted poorer households. However, these households are still at a risk of sliding back to the unacceptable food consumption group. In table 8, we compare

TABLE 7 Average food consumption frequency (number of days) in each Food Consumption Score Group (FSCgp)

	% OF HH	STARCH	VEGETABLE	Fruits	Meat	Legume	Dairy	Oil	Sugar	Average FCS	SD
2016											
Poor consumption	12.06	4.0	2.9	0.5	0.8	0.6	0.4	1.3	1.3	19.3	4.8
Borderline	13.99	6.6	5.7	1.3	1.5	1.6	0.3	4.0	4.3	36.2	3.8
Acceptable consumption	73.95	6.8	6.0	3.2	3.8	3.8	4.4	5.4	2.7	72.2	17.6
All sample		6.5	5.7	2.7	3.1	3.0	3.4	4.6	4.8	60.8	25.0
2018											
Poor consumption	3.41	5.6	4.3	0.3	0.5	0.6	0.0	0.9	1.5	21.8	6.4
Borderline	21.27	6.8	6.1	1.1	1.5	1.7	0.2	2.4	4.8	36.5	3.6
Acceptable consumption	75.32	6.9	6.4	2.6	3.8	3.0	3.1	5.1	6.3	65.1	15.5
All sample		6.7	6.2	2.2	3.1	2.6	2.4	4.4	5.8	57.6	19.1

TABLE 8 Average food consumption score for 2016 and 2018 in intervention and non-intervention wards of Zimbabwe

		NON-INTERVENTION		INTERVENTION		Difference 2018-2016		DID (1-0)
		2016	2018	2016	2018	Non-Intervention	Intervention	
Non-irrigated bean	Mean	67.68***	60.59	50.07	59.11***	-7.09	9.05	16.14***
	SD	22.89	18.40	27.26	17.19	28.78	30.78	
Irrigated farms	Mean	56.64	56.04	56.84	55.71	-0.59	-1.13	-0.54
	SD	27.60	20.61	23.02	18.47	28.94	28.17	
Combined	Mean	62.42***	58.66	55.79	56.65	-3.76	0.87	4.63***
	SD	25.53	19.70	24.56	18.21	28.62	28.98	

food consumption by households in the intervention and non-intervention wards between 2016 and 2018 by production system, i.e. irrigated and rain fed agriculture. These results are consistent with earlier results demonstrated in the distribution graphs. Aggregately, households residing in wards without the intervention experienced a drop in their food consumption score from 62 in 2016 to 59 in 2018. However, this drop occurred among households that farm under rainfall conditions while food consumption remained relatively stable among households farming under irrigation. Across wards with the flagship interventions, food consumption increased for families operating rain fed farms. Using the difference in difference method, our calculated effect of the intervention on food consumption was 4.6 points. This suggests there was a gain of 4.6 points in Food Consumption Score, significant at 1% (Table 8). This is equivalent to a one-day consumption of animal-based meals or two days of cereal based meals for an average family. This change is roughly an increase of 8.3% in food consumption frequency up from the baseline, achieved by households due to accessing the intervention. When we disaggregate the analysis by production systems (irrigated vs non-irrigated), the effect is higher and significant only for households on non-irrigated farms. The DID among the families of the rain fed farms was 16.1 points increase in food consumption and significant at 1% level. In terms of meals, this is equivalent to four days of animal-based meals consumed by an average household. We associated the gain in food consumption among this group to adoption of resilient varieties and organic fertility management practices as earlier discussed.

5.2 Econometric estimation of the impact of the flagship project technology adoption on yield and bean consumption

In this section, we present results on the effect of adoption of multiple technologies promoted under the project on two outcome variables: 1) Bean yield and 2) Bean consumption. The definition and measurement of these variables is described briefly below.

5.2.1 Variables used and estimation strategy

Definition of outcome variables: Bean yield was measured in terms of seed multiplication ratio; whereby quantity of seed planted is used as a proxy for area. Quantity of seed rather than actual area was preferred because the former is less prone to measurement error when data are based on farmer recall. On average, the seed multiplication ratio was 11.1 in non-intervention areas and16.8 among intervention farms. Bean consumption is the total quantity of bean grain in kilograms retained by the household for home consumption, plus quantities purchased or received via food aid during the agricultural season studied.

Definition of adoption variable: The flagship project promoted multiple technologies for managing soil fertility (i.e. organic manure, Rhizobium inoculant and vermi-composite) and new varieties. In the data set collected in 2018, farmers who used at least one of the technologies promoted under the flagship project constituted 61% while those that combined organic soil fertility management inputs and varieties, adopting a full package, were about 11%. The improved varieties included were those supplied to farmers from DR&SS and PABRA through the project. Thus, adopters made their decisions based on a multivariate choice over four technological options: 0) none for none-adoption at all; 1) organic soil fertility management practice only; 2) Improved project variety only; 3) Combination of organic soil fertility and varieties.

Estimation approach: To estimate the impact of the adoption of multiple technologies on bean yield and bean consumption, a Multinomial Endogenous Treatment Effects (METE) model was used. This econometric approach, (used by Manda et al., 2015; Khonje et al., 2018), evaluates the effect of an individual practice and combination of practices, while accounting for interdependency between adoption of alternative practices and possible selection bias (Deb and Trivedi, 2006). Another advantage of METE is that the model can compute and add a latent factor structure to correct for selection bias that may arise due to non-randomness in the adoption decisions when using cross sectional observational data.

The METE is a two-stage estimation procedure that allows modeling the mixed adoption in the first stage as a multinomial selection decision conditioned on variables in the main equation plus instrumental variables to account for unobserved variables. For our case, we used community level exposure to climatic shocks, i.e. drought and floods, during the 5 years prior to the survey[7] as our instrumental variables.
In the second stage, the model estimates the impact of technology choice (i.e. our treatment) on the respective outcome variables (i.e. yield and bean consumption). As estimators in the second stage, we used ordinary least squares (OLS) regression for the yield function and a negative bimodal model for bean consumption, since the latter had a number of zeros. In the second stage of the METE estimation, the respective outcome variable (i.e. bean yield and bean consumption) is regressed on a set of explanatory variables and predicted qualitative indicator of technological choice from stage one and latent factors. For brevity, we do not present a full discussion of the model and its empirical specification, these are discussed in the Annex.

Exogenous explanatory variables: Previous studies on adoption of bean technologies and their impact on respective outcomes (Katungi et al., 2019; Katungi et al., 2016; Letaa et al., 2015; Larochelle et al., 2015) conducted in

7 Variables in the model and their definition.

similar countries guided our selection of the explanatory variables to include in the analysis. These studies suggest that adoption of bean technologies is influenced by various factors such as household characteristics (i.e. age of the head, education level of the head of the household, family size and gender of household head); household wealth assets (livestock, consumer durable goods and agricultural equipment, total cultivable land); market conditions and access to seed and information. Yield is also a function of plot specific characteristics and agronomic inputs used. A full description of the explanatory variables, their descriptive statistics and determinants of improved technology choice for bean production are provided as the Annexes.

5.2.2 Econometric impact results

5.2.2.1 Determinants of technology adoption:

Estimates of the determinants of adoption of non-chemical fertilizers and bean varieties derived from a multinomial model are reported in Table 9. The base-category is non-adoption of any of these technologies indicated in the plots and in the households--meaning that the farmer allocated their land to landraces without any organic fertility management practice. Results in the bottom row of Table 9 are the model diagnostics and show that variables included in the model significantly explain the variations in adoption decisions. Compared to non-adopters, farmers who adopted a combination of organic soil fertility management practices, farm in low elevation areas, are less educated and less likely to use ammonium nitrate after crop germination as top dressing (table 9). Access to a seed dealer is important for adoption of varieties. Results show that farms located within a radius of 5 to 20 km from a seed dealer were 14% less likely to adoption varieties than farmers located in a radius of 0 to 5 km from the seed dealer. The probability of adoption reduces further to 18% for farms located 20 km or more from the seed dealer as compared with those within a radius of 5 km from the same (Table 9). Farmers located far away from seed dealers are likely to choose the option of organic fertilizers only, which means that these farmers may receive information but adoption of varieties remain constrained. The significance of distance to seed dealer in adoption decision, proves its relevance as instrumental variable.

Our results also indicated that the choice of new varieties is positively and significantly influenced by the sex of the household head, and use of inorganic fertilizers especially ammonium nitrate applied after crop germination, i.e. top dressing. This is understandable, since the ammonium nitrate works as a substitute for organic fertilizers. Thus, farmers that use inorganic fertilizers are motived to select only varieties from the alternatives promoted under the project. Adoption of varieties was positively and significantly higher (12%) among male-headed households compared to female-headed households, and increases by 23% as one moves from irrigated to rain fed farms (Table 9).This is surprising, and suggests that given that most of these varieties were climate smart, i.e. resilient to biotic stresses, their benefits are higher on rain-fed farms than irrigated ones,--explaining higher adoption rate. Compared with female-headed households, male-headed households were less likely to adopt a combination of organic soil fertility management practices with varieties. This is probably because such male-headed households are likely to go for inorganic fertilizers while female-headed households are often cash constrained and may prefer less expensive organic fertilizers. Thus, by disseminating information on such management practices jointly with varieties while integrating gender, the flagship project encouraged their uptake by the marginalized families.

The likelihood that a farmer will chose to use organic fertilizers only, was negatively related with most of these factors that increase adoption of varieties. In particular, access to irrigation and size of cultivated land were negatively and significantly associated with use of organic fertilizers. We interpret these findings to mean that use of organic fertilizers is likely to be motivated by constraints of soil fertility degradation and those related with unreliable climatic conditions. Land tenure system faced by the farmer matters when deciding on the technologies for soil fertility management. Results indicate that bean growers farming on land they do not own were less likely to use organic fertilizers, but were 19% more likely to adopt new varieties.

TABLE 9 Mixed multinomial logit estimation of adoption of organic soil fertility management and improved varieties in bean production in Zimbabwe[8]

	ORGANIC FERT ONLY		VARIETIES ONLY		COMBINATION (ORGANIC + VARIETIES)	
VARIABLE	**ME**	**SE**	**ME**	**Se**	**Me**	**Se**
Log of bean area	0.003	0.017	0.007	0.013	-0.005	0.014
Village basal application rate	0.000	0.000	0.000	0.000	0.000	0.000
Village top dresser application rate	-0.205**	0.090	0.250**	0.109	-0.123^	0.071
Irrigation scheme	0.132***	0.045	-0.231***	0.056	0.058	0.041
Household size	-0.011	0.007	-0.005	0.011	0.000	0.008
Age of household head	-0.001	0.001	0.001	0.002	-0.001	0.001
Sex household head	-0.047	0.040	0.121**	0.056	-0.100**	0.046
log village average labour used	0.034**	0.016	0.006	0.025	-0.012	0.019
Hired labour	-0.180***	0.074	-0.055	0.147	-0.007	0.110
altitude	-0.003	0.017	0.046^	0.027	-0.036**	0.016
Membership in association	0.057^	0.033	-0.057	0.048	0.047	0.035
Livestock unit	0.004	0.002	-0.001	0.004	0.003	0.003
Mean of plot slope is medium	-0.131	0.038	0.095^	0.053	-0.082**	0.041
Mean of plot slope is steep	-0.082^	0.051	0.011	0.071	-0.022	0.047
Mean of plot soil is sandy	0.014	0.083	0.005	0.111	-0.033	0.088
Mean of plot oil sandy loam	0.035	0.035	-0.072	0.047	0.018	0.035
Mean land not owned	-0.131	0.097	0.194***	0.082	-0.076	0.072
Years of schooling	-0.006	0.006	0.016**	0.009	-0.013***	0.006
Distance to seed dealer						
Radius of between 5-20km	0.110***	0.051	-0.140***	0.059	-0.037	0.047
Above 20 km	0.109***	0.049	-0.175***	0.061	0.009	0.050
Drought experience						
1	-0.039	0.051	-0.027	0.077	0.039	0.053
2	0.110^	0.066	-0.135	0.134	-0.098	0.101
Number of observations	977					
Wald chi2(66)	127.82			pvalue=0.001		
Log pseudolikelihood	-1099.4					

8 Results are the marginal effects.

5.2.2.2 Impact of adoption on bean yield and bean consumption: Average treatment effects

In the second stage of a multinomial endogenous treatment effects estimation, the study identified the effects of adopting bean technologies in isolation or as a combination, on bean yields and household and bean consumption demand. Our main interest was to identify the impact on yield and bean consumption when producers choose any of the multiple technologies or combinations. Thus, the key findings are the coefficients on technological option and factor loading associated with latent factors for farm productivity and bean demand. A summary of the results from the analysis is presented in Table 10, while results of model diagnostic test to check the validity and robustness of the instruments used in the first stage of the METE, as well as joint significance of the variables in the model, appear in rows at the bottom of Table 11. The falsification test shows that the instruments had no significant effect on yield nor in bean consumption estimated for non-adopting sub-samples. The coefficients (Lambdas) of the latent factors have a significant effect on yield[9] and bean consumption[10], but with different signs. Lambdas for technology subcomponents had negative signs in the bean consumption function, but only the coefficients on varieties as well as organic fertilizers and a combination of variety and fertilizer were significant. The negative coefficient value on these factor loading means that unobserved characteristics that influence these families to choose a combination of varieties and organic fertilizers also lead to a lower yield as well as make these households consume less bean. Similarly, there are characteristics that influence households to choose project varieties only that also lead these households consume less beans. Since these factor loadings represent characteristics missed from the analysis because they were unobserved during the survey, we are unable to discuss these results further.

Effect of multiple technologies on bean yield

Results from econometric analysis are consistent with estimates based on difference in difference method discussed earlier in subsection 5.1., even though DID method gave lower estimates. The model predicts an increase of 74.5% in yield for adopting combination of varieties with organic fertilizers, translating to 7.0 kg of grain per kilogram of planted seed. These results translate to a yield gain of about 347 kg/ha for those farmers that adopted a combination of varieties and organic soil fertilizer management practices. However, this category of farmers that simultaneously

TABLE 10 Multinomial Endogenous Treatment Effects model estimates of bean technology adoption impacts on yield and bean consumption

	COEFFICIENT.	SE.	ATET (%)	ATET (KG)	CHANGE (KG/HA)	P-VALUE
Log of Yield						
Organic soil fertilizers only	-0.065	0.278	-34.47	-0.49	-29.30	0.816
New project varieties only	0.593	0.272	66.56	6.38	339.57	0.029
Organic fertilizers + new varieties	0.709	0.193	74.75	6.95	347.40	0.0001
Amount (kg) of bean consumed						
Organic soil fertilizers only	0.181	0.219	18.126	0.18		0.408
New project varieties only	0.250	0.182	25.046	0.25		0.169
Organic fertilizers + new varieties	0.647	0.187	64.696	0.65		0.001

9 P-value=0.257 for information of conservation agriculture and 0.827 for information on organic fertilizers and 0.524 for joint test of significance.

10 P-value is 0.264, for information on conservation agriculture the only IV used in this model.

TABLE 11 Second stage results of a Multinomial Endogenous Treatment Effects model estimates of bean technology impacts on bean yield and bean consumption demand

	LOG OF YIELD		PER CAPITA BEAN CONSUMPTION (KG)		
	COEFFICIENT.	ROBUST STD. ERR.	COEFFICIENT.	ROBUST STD. ERR.	
Log bean area Ha	-0.026	0.042			
Village basal application rate	0.000	0.000	0.021	0.059	
Village top dress application rate	0.0001	0.291	-0.199	0.262	
Irrigated farm	0.381**	0.166	0.131	0.16	
Household size	-0.005	0.023	-0.122***	0.032	
Age of household head	-0.002	0.004	0.008	0.005	
Sex of household head	0.130	0.128	-0.103	0.141	
Off-farm income			0.0001^	0	
Index for household assets			0.038	0.074	
Index agricultural equipment			-0.002	0.077	
Log of cultivated land			-0.09	0.065	
Log of distance road (km)			-0.002	0.04	
Livestock	0.007	0.009			
Log of altitude	-0.024	0.060			
Hired labour	-0.013	0.371			
Membership in association	0.031	0.112			
Mean of plot slope is medium	-0.164	0.120	0.15	0.113	
Mean of plot slope is steep	-0.159	0.165	0.042	0.151	
Mean of plot soil as sandy	0.510**	0.212	0.118	0.233	
Mean of plot soil as sandy loam	-0.184^	0.113	0.004	0.114	
Mean land not owned	0.264	0.187	0.249	0.17	
Years of schooling	0.035^	0.021	0.026	0.019	
constant	2.278***	0.804			
Agro-ecological zones			0.123	0.263	
2			-0.189	0.245	
3			-0.301	0.249	
4			-0.628**	0.293	
5			-0.502^	0.268	
6			1.436**	0.641	
Lambda (λ)					
/lnsigma	-0.365	0.164			
/ Organic soil fertilizers only	0.137	0.204	-0.255	0.207	0.218
New project varieties only	-0.410	0.271	-0.267**	0.129	0.039
Organic fertilizers + new varieties	-0.486***	0.154	-0.333***	0.126	0.008
Model diagnostic test results					
Number of observation	888.000		617		
Wald chi2(87)	229.9***		11909.3***		
Log pseudo likelihood	-2184.599		-2319.9		
Delta	-0.365	0.164	2.623	0.557	

adopted new varieties and organic fertilizer management practices constituted only 11% of the growers and allocate about 0.62 ha of land to beans. On the other hand, about 36% of the farmers adopted varieties only, and harvested 67% more quantities of bean than they would have harvested if they grew landrace varieties. This translated to a yield gain of 340 kg/ha assuming a seeding rate of 50 kg/ ha and an average yield of 555 kg/ha for the base category, i.e. those growers of landrace varieties and the comparison group. Aggregately, adopters of varieties and those that used a combination of varieties and organic fertilizers harvested an additional 87,14.79 tons of grain valued at USD 13,370,377 from area allocated to either varieties or a combination of varieties and organic fertilizers per cropping season. These results were statistically significant at 5% level. While previous studies have revealed positive and significant effects of improved bean variety adoption on bean yield, these studies did not control for use of management practices that cushion the crop from climatic variability. In this analysis, we attempted to do that by looking at the effect of varieties and management practices when used singularly and in combination. Results reported in Table 9, show that when organic fertilizers or varieties were used in isolation, the effects on bean yield were small (about 67%) compared to 75% gain in yield when varieties are adopted jointly with good agronomic inputs. Thus, there are complementarities between bean varieties and soil fertility management practice, which make them more effective when used in combination.

Other significant determinants of bean yield were plot characteristics and use of irrigation. We found that compared to plots of clay soil type, yield was higher on plots with sandy soil, but lower on those that are of sand-loam (Table 11). As expected, yield is significantly higher on irrigated farms compared with rain fed bean farms.

Effect of multiple technologies on bean consumption

Increasing bean consumption is vital for nutrition security of poorer households, especially now that researchers have developed bean varieties with enhanced Iron (Fe) and Zinc (Zn) content. In 2016, legumes were consumed, on average, 3 times a week in study areas, but less so among households in unacceptable Food Consumption Groups. Two years later, in 2018, the average legume consumption dropped to 2.6 from 3 times a week with an average per capita bean consumption of 5.8 kilograms per agricultural season in 2018. In a multivariate analysis, using METEM , we take a deeper look at the effect of bean technology adoption on per capita consumption quantities[11] among bean-growing households. Results, reported in Table 10, show that the adoption of improved production technologies had a positive effect on household bean consumption demand. But, the effect was significant when varieties were adopted in combination with organic soil fertility management practices. In quantitative terms, simultaneous adoption of improved varieties and organic soil fertilizers increased bean consumption by 9.3% from the average. In other words, households that adopted a combination of technologies increased their bean consumption by 650 grams per person/ per agricultural season. Although this seems small gain, it represent a 11% gain in per capita bean consumption for a typical household, which is a substantial improvement among households that had negative perception towards bean consumption.

Other factors also show significant effects on bean consumption demand. The quantity of beans consumed per person in households is by far lower among larger households and in agro-ecological zones of 5 and 6 that are prone to drought and erratic rainfall (Table 12). As expected, larger household size puts pressure on food availability per person. The lower bean consumption demand may be attributed to erratic rainfall in these areas that may limit food production in general and hence lower food access generally. Therefore, it is important to note that central to increasing bean consumption, especially among the rural population, are efforts to increase bean productivity in these areas and for larger households sizes.

11 The quantity of bean in kg totaled from quantities sourced from own production + purchased + received through food aid.

6.0 Conclusion

The Government of Zimbabwe, through the DR&SS and AGRITEX, jointly with ABC under the PABRA umbrella, have promoted bean technologies in the country under the flagship project launched in 2015. This study was undertaken to monitor progress in outcomes towards the project goal of increasing household livelihoods via improved bean production and utilization. Six varieties of improved beans were released to communities between 2015 and 2019, two of them biofortified with high iron (Fe) and zinc (Zn) content to tackle malnutrition and nutrient deficiencies, while four are resilient to climate-related stresses like drought and disease. These were disseminated together with four varieties that existed at the time of project launch to farmers under the seed system component of the project. Consistent with project implementation data, the study found that farmers had increased access to and utilization of new varieties. Similarly, there is an improvement in the use of organic soil fertility amelioration that are of low cost and environmental friendly, but their use in absolute terms is still modest. About 36 % used varieties only in 2018 and 11% combined these soil fertility management practices with varieties. Adoption of these technologies has a positive and significant effect on bean yields of higher magnitude. This has important policy implications. For example, future interventions aimed at disseminating market preferred varieties can combine them with good and sustainable management practices to achieve multiple objectives. These include increased productivity while meeting the preferences of the market and protecting the environment. Since the adoption of organic climate-smart management practices highly depends on access to information, continuous training of farmers about their benefits and implementation is vital for their adoption.

The study findings also revealed that the project contributed to closing the gap between high and low-performing farms. Farmers that were at the tail-end of yield distribution in 2016, have increased their yield and improved food security. Farmers without access to irrigation and thus vulnerable to climatic variability have benefited from resilient varieties and have been able to increase their yield by 66% and 75% when the varieties are managed with organic fertility management practices. For example, of households that were classified as having an unacceptable FCS in 2016, at baseline, about 10% used a combination of varieties and soil fertility management practices, enjoying yield increase amidst unfavourable climatic conditions. As a result, there was a reduction of 8.7% in the number of household classified under unacceptable FCS, from a baseline of 12% in 2016.

The study found that the quantities of bean consumed by adopters increased, suggesting that through yield gains, the project has contributed to bean consumption. However, we observed that growth in bean consumption was heavily dependent on own production as a source compared to buying from the market; thus vulnerable to weather variability for many households that lack access to irrigation facilities. Fortunately, the study findings demonstrate that the impacts of the project flew to families producing beans under rain-fed system—thereby highlighting the strategic importance of resilient varieties in sustaining bean consumption. As varieties that are more resilient have been released under the project, their continued dissemination targeting to reach more farmers is anticipated to sustain the project impacts on yield, contributing to household welfare. However, the importance of this contribution was higher for households that were able to adopt a full package of technologies that represented only 11% of the farmers. Since bean consumption is vital for nutrition, further gains in bean consumption among rural smallholders in Zimbabwe will require concerted efforts to intensify bean production in different agro-ecological zones.

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Alliance

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PABRA
Pan-Africa Bean Research Alliance
Better Beans for Africa

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Schweizerische Eidgenossenschaft
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